TIME AND FREQUENCY SYNCHRONIZATION (T&F SYNC) COMMON AND STANDARDIZED ARCHITECTURE FOR DOD SHORE COMMUNICATION STATIONS

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Abstract

Time synchronization and frequency syntonization are vital to all mission-critical DOD C4ISR systems to ensure accurate data processing and timely information transmission and reception. Existing Time and Frequency Synchronization (T&F Sync) systems at Navy shore communication stations have evolved over many years and are often unique, stand-alone, site-specific configurations having been implemented for a number of specific system designs to meet a variety of specifications, standards, and requirements. These systems are composed of an eclectic and varied mixture of military and Commercial-Off-The-Shelf (COTS) equipment, many of which are legacy, obsolete, or discontinued models.

Under the sponsorship of SPAWAR 05 and PEO C4I & Space/PMW-170 (formerly PMW-156), SSC-SD has evaluated available COTS T&F Sync equipment configurations. These configurations were evaluated for potential operation in accordance with JCS (Joint Chiefs of Staff) requirements, as well as current and future military requirements. From this evaluation the architecture for a common T&F Sync equipment configuration for shore communication stations was determined. Coordination of this proposed architecture with personnel from the sponsoring activities, the Defense Information Systems Agency (DISA) and the Naval Research Laboratory (NRL) has resulted in a final T&F Sync architecture solution that has been proposed for implementation. The proposed architecture is the subject of this paper.

The goal of implementing this T&F Sync architecture is to provide a common technical architecture for all DOD shore communication stations that can satisfy current requirements and be expanded to meet future requirements.

INTRODUCTION

Time synchronization and frequency syntonization are vital for military systems to ensure accurate data processing and meaningful, reliable information, transmission, and reception. The Time and Frequency Synchronization (T&F Sync) infrastructures currently implemented at Naval Computer and Telecommunications Area Master Stations (NCTAMS) and Naval Computer and Telecommunications Stations (NCTS) located around the globe are required to providing reliable,

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14. ABSTRACT

Time synchronization and frequency syntonization are vital to all mission-critical DOD C4ISR systems to ensure accurate data processing and timely information transmission and reception. Existing Time and Frequency Synchronization (T&F Sync) systems at Navy shore communication stations have evolved over many years and are often unique, stand-alone, site-specific configurations having been implemented for a number of specific system designs to meet a variety of specifications, standards, and requirements. These systems are composed of an eclectic and varied mixture of military and Commercial-Off-The-Shelf (COTS) equipment, many of which are legacy, obsolete, or discontinued models. Under the sponsorship of SPAWAR 05 and PEO C4I & Space/PMW-170 (formerly PMW-156), SSC-SD has evaluated available COTS T&F Sync equipment configurations. These configurations were evaluated for potential operation in accordance with JCS (Joint Chiefs of Staff) requirements, as well as current and future military requirements. From this evaluation the architecture for a common T&F Sync equipment configuration for shore communication stations was determined. Coordination of this proposed architecture with personnel from the sponsoring activities, the Defense Information Systems Agency (DISA) and the Naval Research Laboratory (NRL) has resulted in a final T&F Sync architecture solution that has been proposed for implementation. The proposed architecture is the subject of this paper. The goal of implementing this T&F Sync architecture is to provide a common technical architecture for all DOD shore communication stations that can satisfy current requirements and be expanded to meet future requirements.

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highly accurate, and stable time synchronization and frequency syntonization references. Users of these capabilities and services require accuracy and/or stability references to maintain critical strategic and tactical communication links throughout U.S. advanced forces.

REFERENCE TIME GENERATION AND DISSEMINATION

Time and frequency references provided by NCTAMS and NCTS form a vital part of the systems architecture of common references for the military forces. The systems architecture for providing a Common Time Reference (CTR) **[1]** is illustrated in Figure 1. There are basically three primary elements to this architecture, which are: (1) the reference timescale, (2) dissemination of the reference, and (3) the user infrastructure that uses the reference and distributes it among the users.

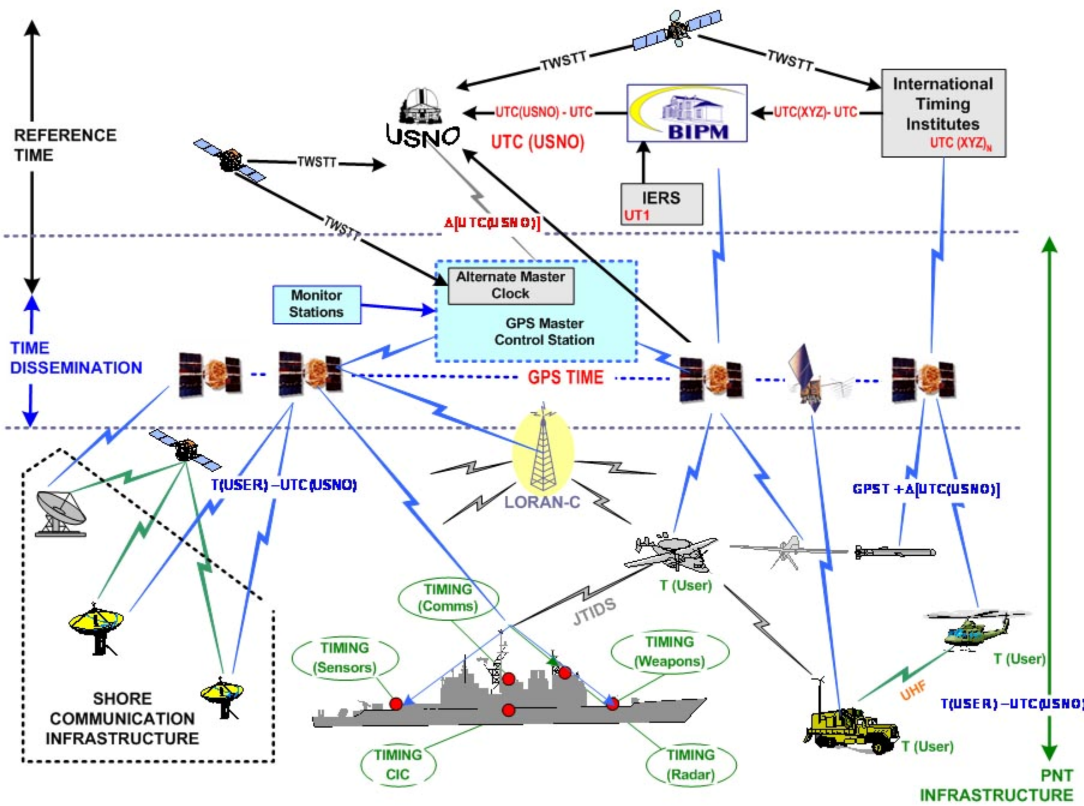

Figure 1. Time Generation and Distribution

REFERENCE TIME

The timescale adopted for DoD systems is Coordinated Universal Time (UTC) as maintained by the U.S. Naval Observatory, designated UTC (USNO) **[2]**. The UTC timescale is the international timescale that is the basis of telecommunications broadcasts and measurements. UTC is formed from International Atomic Time (TAI) and Universal Time that is corrected for the rotation of the earth, designated UT1. TAI and consequently UTC are based on the international standard SI second, which is based on a cesium hyperfine resonance frequency. TAI is a continuous timescale generated from measurements of atomic frequency standards distributed around the world and coordinated by the International Bureau of Weights and Measures (BIPM),

an international agency located in France. By definition, UTC and TAI have the same rate, but UTC is maintained to within 0.9 seconds of UT1 by adding or subtracting an integer number of seconds, so-called leap seconds, as necessary. UTC is then the composite of measurements made at numerous time centers around the world. It is the standard for legal and scientific measurements. The definition, method of generation, and utilization of UTC is standardized through Recommendations of the International Telecommunications Union – Radio communication Sector (ITU-R) **[3]**.

Since UTC and TAI are determined after the fact from international time and frequency measurements, local or national timekeeping centers maintain their own physical realization of UTC as a designated output of a local clock **[4]**. To distinguish this local signal from a "paper" or theoretical clock, each timing center's representation is identified as UTC (XYZ), where XYZ is the center.

UTC presents a unique problem for the military user in that it is not uniform. Leap seconds produce an unpredictable nonuniformity whose distribution of the information to determine when to introduce the step has presented problems. The design of many military systems does not account for the possibility of non-continuous time, and UTC is used as an approximation of UT1 that is needed to orient inertial systems. In situations where joint operations involve NATO or Allied forces, the timescale in use by those forces may be an issue. Accuracy and availability of UTC sources differs from nation to nation. These CTR architecture issues are being addressed in conjunction with standardization of the shore establishment.

TIME DISSEMINATION

Dissemination of time accurately and precisely carries the time and frequency generated by the reference timescale out to the diverse mobile and fixed systems that provide the instrumentation and technology for its accurate application. This involves significantly different problems. The primary means of accurate time dissemination is the Global Positioning System (GPS). GPS uses a constellation of satellites each containing four atomic clocks that are used in establishing GPS Time, the common GPS system synchronization time. Time dissemination with GPS takes two forms: (1) passive time transfer used predominately by the DoD operating forces and (2) Common View Time transfer or differential GPS used for scientific and international timescale operations. Each technique will be discussed separately, since they have differing capabilities and applications.

PASSIVE GPS TIME TRANSFER

Using GPS for mission critical combat and weapons systems relies upon the stability and precision of GPS Time for positioning and time transfer received through the military encrypted satellite signals, known as P(Y) Code transmissions. Simultaneous passive reception of multiple GPS satellites requires the satellites to be precisely synchronized to each other with less error than that expected from the individual satellite pseudorange measurement with the user receiver. The stability of the individual satellite clock between updates or re-synchronization with GPS Time determines the system synchronization error. Signal propagation of the GPS signals, receiver instrumentation, user position uncertainty, and UTC (USNO) satellite correction message offset are the other determining factors in passive time transfer accuracy to the operating forces. The accuracy of this capability is evaluated at USNO in the operational determination of the GPS Time - UTC (USNO) offset for inclusion in the GPS satellite messages to the user.

This passive technique is the primary mode of time transfer operation for the military user. As a passive service the GPS broadcasts are available over a wide area independent of the user's position for reception. The timing information is determined along with the position and velocity in the user's calculations during flight or other operations. Consequently, estimates of time transfer accuracy are dependent upon the uncertainty of the user's location in the navigation process. For fixed sites with accurate knowledge of position, such as at USNO, near optimum results less than 10 nanoseconds, 1 σ, can be expected. Effective use of this capability in mobile platforms is dependent on the user's instrumentation and ability to use the high precision timing information.

Use of GPS for military positioning and timing input to communications systems has been identified as a major vulnerability. Backup and alternative systems to provide precise time are not generally available. Techniques to provide precise time in the absence of GPS and means of maintaining multiple systems on a common time are being investigated.

COMMON VIEW GPS TIME TRANSFER (DIFFERENTIAL GPS)

GPS time transfer between the worldwide timing centers and the scientific community utilize another technique known as Common View and its variant, Carrier Phase Common View. Common View is a point-to-point technique rather than a general broadcast as in the passive reception case discussed above. Two sites requiring time transfer exchange pseudorange measurements taken from individual GPS satellites. Differencing these pseudorange data results in a precise comparison between the local clocks at the two sites. Carrier phase measurements increase the precision of the pseudorange or range measurement between the receiver and the individual satellite. Increased precision results from measuring the ambiguous RF carrier phase rather than the unambiguous code modulation. The ambiguity of the continuous RF signal results in precise frequency values rather than time values. Development of techniques to utilize GPS carrier phase in operations is being conducted by USNO as part of the International GPS Service (IGS). The participating IGS stations and analysis centers have been able to achieve sub-nanosecond precision frequency comparisons between the participating network of stations. USNO is cooperating with the IGS network frequency comparisons in a pilot project with the IGS and BIPM. Results to date have indicated that to achieve the full capability of this technique, technology to calibrate the receiving systems at picosecond levels must be developed.

Calibration of geodetic receiving systems by using GPS system simulators is the subject of a small effort at NRL. This technique, which provides complete control of all the conditions of signal reception, offers the potential of an absolute calibration for determination of time epoch transfer.

TWO-WAY SATELLITE TIME TRANSFER (TWSTT)

The most precise time transfer technique in use today is TWSTT. This technique takes advantage of the two-way capability of communication satellites (Comsats) to transmit timing signals in both directions to virtually eliminate the transmission and common instrumentation delays between the two participating sites. It is a point-to-point technique used primarily between timing centers suitably equipped. Originally pioneered by the Institute of Navigation (ION) in Stuttgart, Germany, NRL designed and built a series of new digital TWSTT modems to develop the technology, transfer the manufacturing capability to industry, and apply the technology to other special timing developments. These modems were designed to transmit data along with the timing signal so that an additional data link is not required and a complete time transfer can be accomplished in one session through the Comsat. The TWSTT modem takes the output One

Pulse per Second (1PPS) output from its local clock to generate a pseudo-random ranging code for transmission by a Comsat ground terminal. The ranging signal occupies about 2 MHz of bandwidth. The modem can operate with any Comsat terminal, but in general, Very Small Aperture Terminals (VSATs) are mostly used that operate through commercial Comsats. Other links used include mobile X-band terminals for the Defense Satellite Communications System (DSCS) and C-band INTELSAT system. The receiving terminal listening to the Comsat downlink, addressed by a unique identifier, demodulates the code, compares the re-generated 1PPS with its own, encodes the comparison with other site data, and responds with a similar code generated from its local clock. An interchange of ranging signals follows that provides a number of time transfers during the short communications session. The single measurement precision of a single two-way transfer is approximately 10 picoseconds. Overall accuracy is dependent upon non-reciprocal instrumentation and satellite transponder delays, and possible satellite motion during the transfer process. Time transfer accuracies of 100 picoseconds are theoretically possible if the non-reciprocal errors can be sufficiently reduced.

Extension of this technique to mobile platforms could provide an alternative means of providing precise time to the operating forces. By using existing communications systems combined with a smaller ruggedized modem could disseminate highly precise and accurate time to multiple points. Investigation of this technique could encompass the new Global Broadcast Systems and other new communications capabilities being developed.

INDIRECT TIME TRANSFER

The methods discussed above are what could be called "direct" time transfer systems. They are either designed specifically for time transfer, such as TWSTT, or use time synchronization as a primary means for operation, such as GPS. Other relative tactical communications systems, such as Havequick, are designed to use relative timing information for synchronization of tactical communications protocols and data transfer. These relative systems can potentially be used to distribute, over their local area of coverage, timing information derived from GPS or other sources as an alternative time transfer mechanism. The capability of these systems to supplement GPS time transfer is being investigated. The technical limitations of these alternative systems are the external timing interfaces used and the ability to output sufficiently high quality information for absolute time transfer application. Internal system delays unimportant for relative operation can be major problems for absolute time transfer accuracy. SPAWAR Systems Center, San Diego and NRL are investigating these applications and systems with NAVSEA.

T&F SYNC ARCHITECTURE OBJECTIVES

The main objective of the proposed architecture is a common Shore Station architecture for Navy and Defense Information Systems Agency (DISA) **[5]** communication stations. This architecture would ensure the NCTAMS and NCTS are capable of meeting the stricter synchronization requirements and common time reference goals required to enable FORCEnet network centric initiatives and the Global Information Grid (GIG) **[6]**. The resultant infrastructure is depicted in Figure 2.

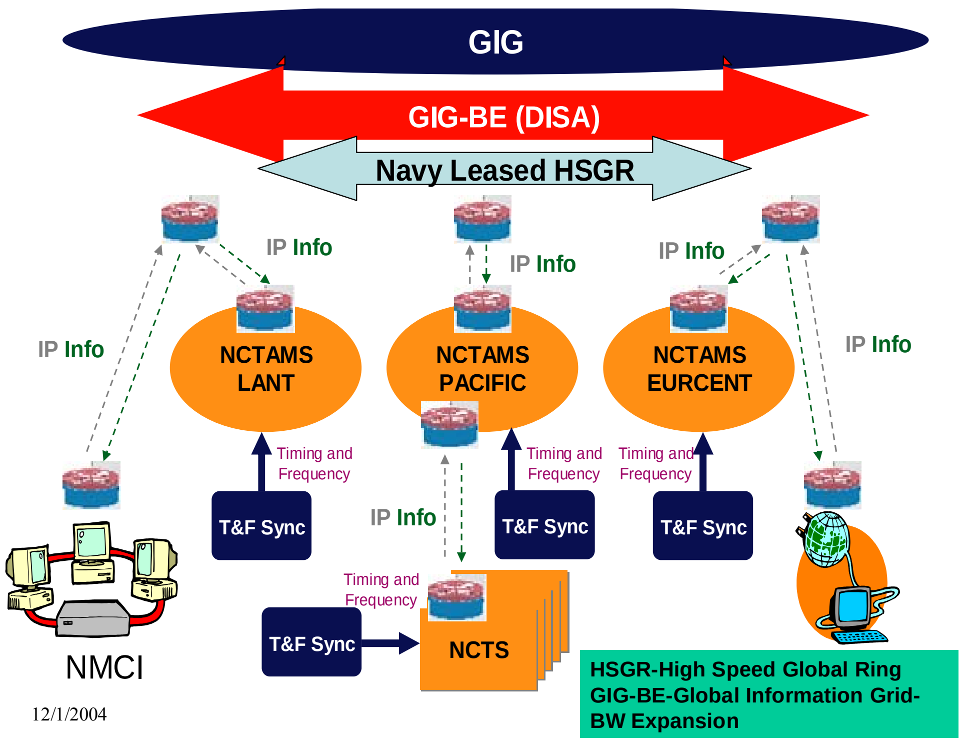

Figure 2. T&F Sync Infrastructure Role in the GIG

The architecture must provide end-users with the best value performance that existing technology can deliver. Critical performance objectives are aligned with CJCSI **[2]** objectives, which include:

- **Survivability & Robustness**: The architecture must be as survivable and robust as the forces and systems it supports. System component redundancy should be used in the design to ensure continuous operation to end-users and prevent single-point modes of failure.

- **Signal Quality**: Signals generated by T&F Sync system components must be of the highest practical quality in terms of accuracy, precision, and stability. Where available, system integrity monitoring features must be used.

- **Minimizing Service Interruptions**: T&F Sync must minimize the impact of service interruptions due to individual component failures, and human error. System components must be operationally isolated and independent of each other.

- **Modular Design Approach**: All components should use a modular design approach that is scalable to meet specific site installation requirements. Each system component should use optional I/O modules to permit custom configuration to meet end-user signal requirements. This will also improve component fault isolation and reduce repair costs.

PROBLEMS AND ISSUES

Currently, there isn't a commonly defined architecture for existing T&F Sync infrastructures at NCTAMS and NCTS. Existing T&F Sync systems are often stand-alone, site-specific in architecture, configuration, and implementation of system-unique design to meet a variety of specifications, standards, and requirements set forth by the end-users. These systems are composed of a rich and varied mixture of military and COTS (Commercial-Off-The-Shelf) equipment many of which are legacy, obsolete, and discontinued.

The T&F Sync infrastructures at NCTAMS and NCTS have been experiencing the following problems/issues:

- **Policy, Instructions [2], [7]**: Many currently fielded T&F Reference Sources use GPS timing receivers and will soon be out of compliance with the appropriate DoD mandates. Most of these sources are C/A-code SPS (Standard Positioning Service) receivers, with the exception of a few P(Y)-code PPS (Precise Positioning Service) receivers. The 2003 CJCS Master Positioning, Navigation, and Timing Plan (CJCSI 6130.01C) mandates the use of SAASM-based GPS PPS receivers operating in the PPS mode for all military applications (as of October 2006).
- **Support, Maintenance, Replacement[1]**: The increasing diversity of T&F Sync equipment currently in use has resulted in a plethora of support, maintenance, and replacement issues.
- **Accuracy, Stability, Reliability**: Many existing T&F Sync systems have become obsolete and/or discontinued. These fielded systems may not be able to reliably provide highly accurate and stable time and frequency references to user equipment with the most stringent requirements.
- **Interoperability [8-13]**: The lack of a common T&F Sync architecture, the diversity of installed equipment, and no configuration management have created interoperability issues.
- **Performance/Integrity Monitoring**: Current T&F systems use GPS as the Primary Reference Source (PRS) and do not provide for a non-GPS backup [Secondary Reference Source (SRS)]. In addition, most fielded T&F systems do not have a performance monitor capability that monitors the accuracy and stability of each T&F Sync source.

REQUIREMENTS

With the proposed T&F Sync architecture we attempt to satisfy the following requirements:

a. Common time and frequency architecture

- Modular design approach that is scalable to support a variety of installation configurations
- Avoidance of vendor-unique solutions to reduce sole-source dependencies
- Flexibility to accommodate future technology insertion
- Expandability to meet future end-user T&F requirements

[1] These issues are not the subject of this paper.

- Multiple levels of redundancy for fault tolerance
- Maximized use of standard hardware components

b. Compliance to CJCSI 6130.01C and CJCSI 6212.01C[2]

- PPS GPS timing receiver to be the PRS
- PRS to satisfy Joint Program Office (JPO) approved SAASM security architecture
- Non-GPS based backups (SRS and Tertiary Reference Source (TRS), e.g. cesium, rubidium, OCXO clocks) will provide a "holdover" capability during loss of GPS
- Evaluation and certification by the DISA Joint Interoperability Test Command (JITC)

c. Personnel Constraints

- New T&F Sync system must be operated and maintained using reduced personnel levels

PROPOSED T&F SYNC ARCHITECTURE

Figure 3 is the overall functional block diagram of the proposed T&F Sync architecture. The architecture consists of four functional components:

- Primary Reference Source (PRS)
- Secondary Reference Source (SRS)
- Tertiary Reference Source (TRS)
- T&F Distribution Unit (TFDU)

Three independent Reference Sources (PRS, SRS, TRS) feed the T&F Distribution Unit. The Source Selector section monitors the quality of each reference signal connected to the TFDU and determines the best available reference (based on the best two of three sources). The input source selection is made using the "tri-corner hat" method. Given three independent[3] input sources, each source is compared to the other two to determine the source that is relatively the most stable.

[2]Equipment from several T&F vendors has been JITC-certified by DISA such as TT56000, SSU-2000, CommSync II, TSG-3800. See *http://jitc.fhu.disa.mil* for more information.
[3]Sources are independent at all times except during the time that the PRS is disciplining the SRS and TRS.

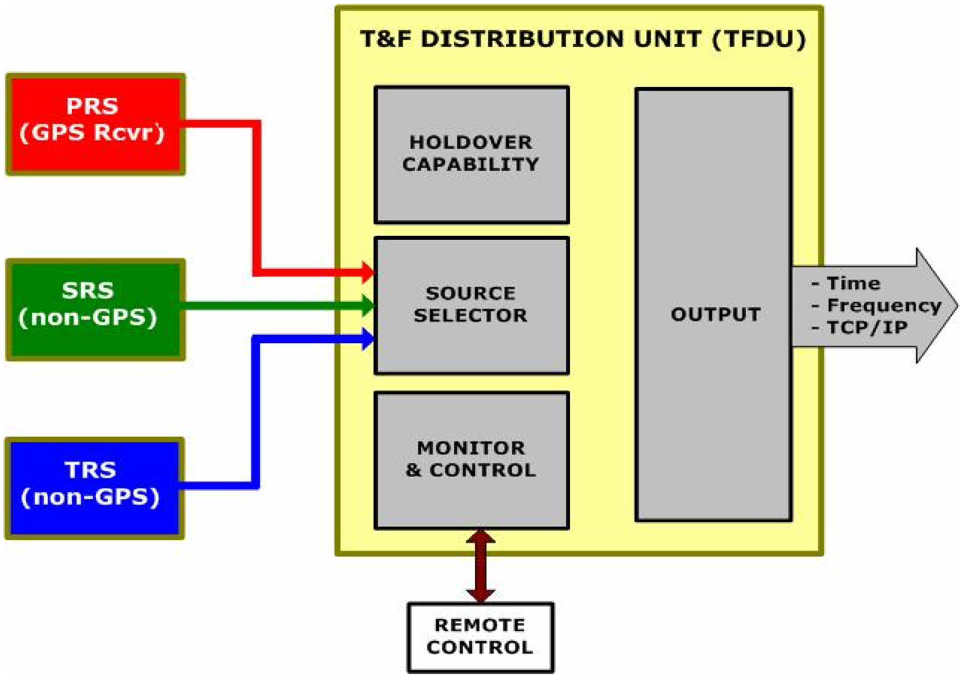

Figure 3. T&F Sync Overall Architecture Functional Block Diagram

If the sources are denoted as A, B, and C, three variances of relative stability are derived: $\sigma_{AB}^2, \sigma_{AC}^2, \sigma_{BC}^2$.

$$\sigma_{AB}^2 = \sigma_A^2 + \sigma_B^2, \qquad \sigma_{AB}^2 : \text{variance (error) combined from both clocks A and B}$$
$$\sigma_{AC}^2 = \sigma_A^2 + \sigma_C^2, \qquad \sigma_{AC}^2 : \text{variance (error) combined from both clocks A and C}$$
$$\sigma_{BC}^2 = \sigma_B^2 + \sigma_C^2, \qquad \sigma_{BC}^2 : \text{variance (error) combined from both clocks B and C}$$

$$\sigma_{AB}^2 + \sigma_{AC}^2 = 2\sigma_A^2 + (\sigma_B^2 + \sigma_C^2) = 2\sigma_A^2 + \sigma_{BC}^2$$
$$\sigma_{AB}^2 + \sigma_{BC}^2 = 2\sigma_B^2 + (\sigma_A^2 + \sigma_C^2) = 2\sigma_B^2 + \sigma_{AC}^2$$
$$\sigma_{AC}^2 + \sigma_{BC}^2 = 2\sigma_C^2 + (\sigma_A^2 + \sigma_B^2) = 2\sigma_C^2 + \sigma_{AB}^2$$

We have three linear equations that tie the three unknowns of the single clocks to the known variances of the combined clocks. Determining which of the σ is the smallest (i.e. indicating relative stability) is straightforward and its corresponding source is then used as the input.

$$\begin{cases} \sigma_A^2 = 0.5(\sigma_{AB}^2 + \sigma_{AC}^2 - \sigma_{BC}^2) \\ \sigma_B^2 = 0.5(\sigma_{AB}^2 + \sigma_{BC}^2 - \sigma_{AC}^2) \\ \sigma_C^2 = 0.5(\sigma_{AC}^2 + \sigma_{BC}^2 - \sigma_{AB}^2) \end{cases}$$

Then the Source Selector switches this best Reference Source to the Holdover section. The Holdover section provides a stable and "glitch-free" Reference Source to the Output Modules installed in the Output Section.

Figure 4 provides a more detailed view of the major components of the T&F Sync architecture. Each component is explained in the following subsections.

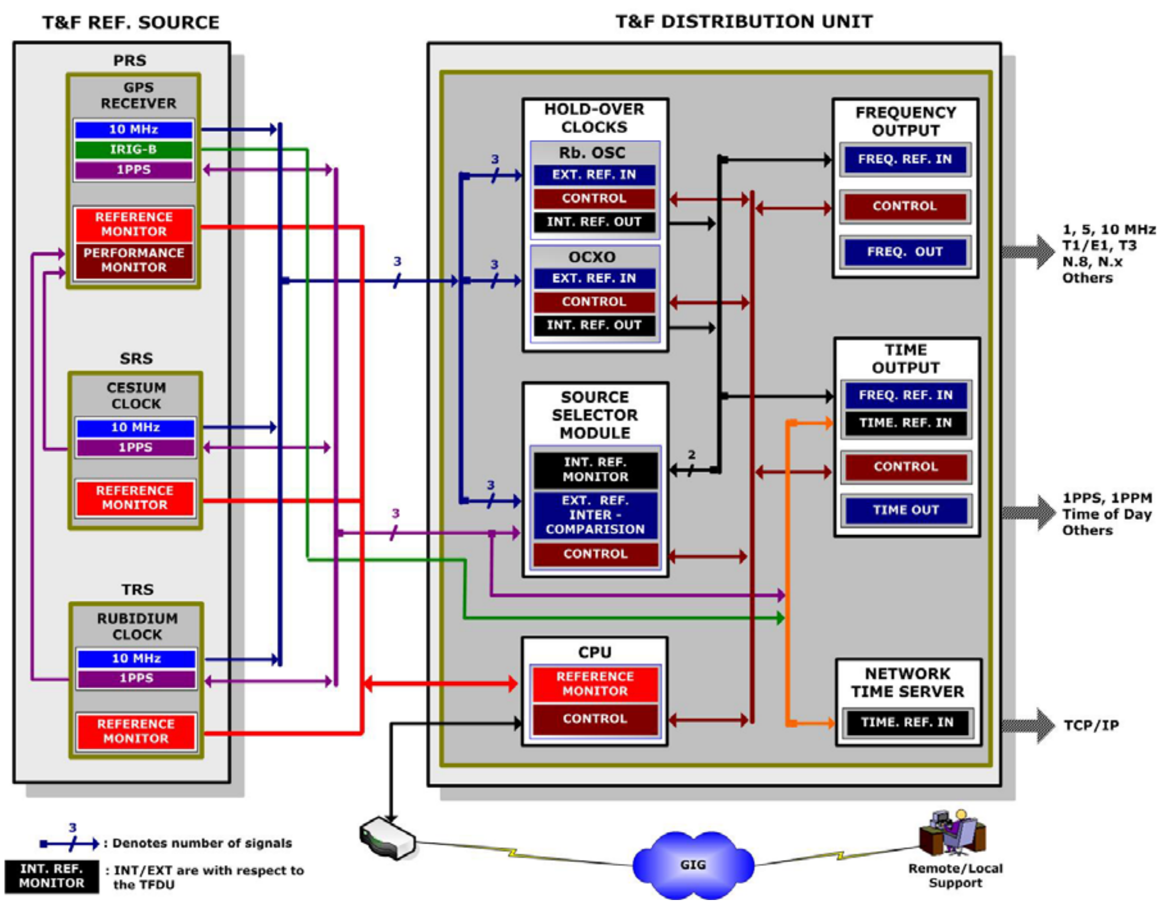

Figure 4. T&F Sync Detailed Architecture

PRIMARY REFERENCE SOURCE

Starting in October 2006 to satisfy CJCSI 6130.01C directives, the PRS must be a JPO-approved, SAASM-compliant GPS Timing Receiver. The PRS must generate reliable, accurate, and stable

standard T&F reference signals [e.g. 1PPS, 10 MHz, and Time Of Day (TOD)] with stratum 1 accuracy (i.e. equal or better than 1 part per 100 billion or 1×10^{-11}) and traceable to UTC (USNO).

The PRS should provide a dedicated Local Monitor/Control Port that should accommodate use of either a Serial RS-232/422 or RJ-45 Ethernet interface. In addition, local PRS monitoring and control should be available from an optional front panel display and keypad.

The PRS should provide a dedicated Reference Monitor Port (RS-485 or RJ-45 Ethernet) that is be used to communicate PRS status and control to the TFDU.

The PRS is to include an integral Performance Monitor (PM) capability. The PM continuously monitors and simultaneously analyzes the 1PPS signal quality characteristics of the PRS, SRS, and TRS. It detects subtle signal quality degradations (e.g. slow frequency drift, excessive wander or jitter) well before they severely impact TFDU output signal quality. Upon reaching predefined signal error thresholds, the PM reports to the TFDU the error condition. The TFDU CPU will process this error and issue the appropriate corrective (e.g. discipline the SRS or TRS with the 1PPS from the PRS).

SECONDARY AND TERTIARY REFERENCE SOURCES

The Secondary and Tertiary Reference Sources must satisfy the CJCSI 6130.01C directive that a non-GPS backup reference be used to provide a holdover capability during GPS outages (i.e. jamming, spoofing, etc.). Since the PRS (PPS GPS Timing Receiver) normally provides a stratum 1 level of accuracy, the backup SRS and TRS should maintain the same level of accuracy. Therefore, a cesium and GPS-disciplined rubidium clocks are suggested.

SRS and TRS clock operation should be completely automated, with minimal need for user controls. The SRS and TRS should each provide a dedicated Local Monitor/Control Port that can accommodate either a Serial RS-232/422 or RJ-45 Ethernet interface. In addition, each unit provides local monitoring and control from an optional front panel display and keypad.

The SRS and TRS should provide a dedicated Reference Monitor Port (RS-485 or RJ-45 Ethernet) that is to be used to communicate device status and control to the TFDU.

The SRS (cesium) and TRS (rubidium) clocks must be periodically time-synchronized and disciplined by the PRS (GPS). Upon reception of a “Sync” command over the Reference Control bus, the SRS or TRS will automatically synchronize to the 1PPS reference input pulse to within 50 ns.

T&F DISTRIBUTION UNIT

The TFDU consists of the following subsections.

Reference Source Inputs

Reference Source Inputs receive inputs from at least three independent external reference sources (Primary, Secondary, and Tertiary References).

T&F Output Modules

T&F Output Modules generate user-configured time and frequency signals that are disciplined to the active reference source. Optional Frequency Modules generate and distributes stratum 1 frequency signals of various rates and formats (e.g. 1, 5, 10 MHz, T1/E1, T3 **[14]**, N.x (e.g. N.1, N.8), and user-specific rates/frequencies). Optional Timing Modules generate UTC (USNO) time sync signals of various rates and formats (e.g. 1PPS, 1PPM, Time of Day).

An optional Network Time Server Module should support multiple time transfer protocols (e.g. NTP, SNTP).

All T&F Output Modules should offer fiber optic interface options required for red/black security interfaces.

Holdover Oscillators

Holdover Oscillators are arranged in a dual-redundant configuration and are constantly disciplined by the active reference source. They ensure that user T&F signal outputs are stable during external reference signal switching.

Source Selector Module

The Source Selector module performs Inter-Reference Comparisons between at least three of the external reference sources (PRS, SRS, TRS) and the two holdover oscillators for integrity checking. This Source Selector module monitors overall TFDU system performance and recommends the best available reference signal source.

The Source Selector metrics should include, but are not limited to:

- Frequency Offset (i.e. frequency deviation and fractional frequency offset)
- Allan Deviation (ADEV), Allan Variance (AVAR)
- Modified Allan Deviation (MADEV), Modified Allan Variance (MAVAR)
- Time Deviation (TDEV), Time Variance (TVAR)
- Root mean square of Time Interval Error (TIE_{rms})
- Maximum Time Interval Error (MTIE)

The above metrics should be averaged over a wide range of measurement time intervals.

The Source Selector module supports automatic reference source switching from a faulty source to a healthy source based on user-configured thresholds. This module also monitors the performance of the dual holdover oscillators in order to ensure that the unit with the best performance is functioning as the active reference and feeding all the T&F Output Modules.

The Source Selector module Inter-Reference Comparison capability should perform the following basic functions:

- Measurement and acquisition of phase and time offsets (where applicable) among multiple signals
- Evaluation of synchronization quality quantities based on the acquired data sets (e.g., predicted equivalent slip rate, and the standard stability quantities of Allan deviation, MTIE and TDEV)

- Performance correction/adjustment and performance reporting

Central Processing Unit (CPU)

The Central Processing Unit monitors both the external Reference Monitor bus and the internal Fault Monitor bus for reference source or holdover oscillator signal faults. The CPU processes all received errors/faults and communicates the corrective action. The CPU uses the Fault Monitor bus to communicate status/control commands to all devices within the TFDU. If the fault involves an external reference source, the CPU controls the device over the Reference Monitor bus. The CPU determines which holdover oscillator is the active reference to each Output module. The CPU commands the Source Selector module to switch the best available references source to each Output module. This module should support remote TFDU system monitoring, command, control, and configuration over TCP/IP network with HTML-based Web browser). The CPU responds to anomaly indications detected by the PRS Performance Monitor. It uses the Source Selector Module to verify the signal quality of all reference source and holdover oscillator signals. All necessary reference source corrective actions (e.g. disciplining) are always initiated by the CPU.

CONCLUSION

FORCEnet and the increasing demand for systems to support network centric warfare has dramatically increased the need for reliable, accurate, and stable timing and frequency distribution systems. The proposed Performance Monitoring capability will ensure that all DoD T&F Sync Distribution systems deliver the highest possible robust levels of performance. Advances in atomic oscillator technology (i.e. MEMS Chip Scale Atomic Clocks) will enable the proposed PM technology to be implemented at an extremely competitive cost, considering the potential benefits.

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[12] Public Law 100-223.

[13] Policy, Second Draft; "*Presidential Decision Directive*," 29 March 1996, NAVWAR capability.

[14] ITU-T Rec. G.702, 1988, "*Digital Hierarchy Bit Rates"* (Blue Book, Geneva).